# The Formation of Sedimentary Strata on Continental Margins

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## LONG-TERM GOALS

The ultimate goal of this research is to understand the mechanisms by which continental-margin sediment is deposited, modified and preserved, so strata recorded over various time scales (events to millennia) can be interpreted better.

## OBJECTIVES

The fieldwork is undertaken on the Eel margin within the larger context of the STRATAFORM program, and has objectives that complement those of other groups. In particular, this project is designed to document event beds (i.e., flood, storm) immediately after they form, to observe their subsequent modification and preservation, and to interpret geologic history from old beds buried at various depths within the seabed (10s of centimeters to meters). Another objective is to examine, the dispersal and deposition of sediment escaping the shelf and reaching the continental slope. An objective to examine the sedimentary character of the sandy inner shelf was recently added.

In addition, the overall STRATAFORM program is coordinated through efforts to: orchestrate program planning, organize field operations, and disseminate scientific results.

## APPROACH

Rapid-response box coring occurred immediately after two very large floods of the Eel River (Jan 95 and Jan 97) and a large ocean storm (Dec 95). Subsequently, the shelf and slope have been examined several times each year by box coring, piston coring, and recently by vibracoring. Investigations of sediment size and fabric are put into a chronologic context using a suite of radioisotopes ($^{7}$Be, $^{210}$Pb, $^{137}$Cs, $^{14}$C), which are relevant for a variety of time scales (months to millennia).

Monitoring of sediment escape to the continental slope is performed at a mooring located north of the Eel River mouth in a water depth of 450 m (at site Y450). Three sediment traps (depths of 65, 200, 435 m) are maintained continuously, and the temporal variability of sediment fluxes (quantity and composition) is observed on time scales of 10-16 days in sequentially rotating cups. During FY00, replicate surveys of nepheloid layers (through CTD-transmissometer profiling) were undertaken near the Y and O transects and at the head of Eel Canyon. Over a range of seasons, the head of Eel Canyon was investigated by coring the seabed. An additional, water-column mooring and seabed tripod were deployed at the entrance to the canyon during winter 1999-2000.

## WORK COMPLETED

During FY00, seabed samples and suspended-sediment data were collected on four cruises. On the *R/V Wecoma* in October 1999, January 2000, and April 2000 samples and data were collected from the shelf, slope and in the head of Eel Canyon. In July, a longer cruise (*R/V Thompson*) obtained a variety of core samples, but focused on vibracores between water depths of 20 m and 50 m. During all four cruises, mooring/tripod instrumentation was deployed and/or recovered. A fifth cruise in March 2000 (*R/V Thompson*) allowed for testing of the PROD system.

## RESULTS

### *a) Characterization of inner-shelf sand deposit*

During the past year, three distinct sedimentary styles have been identified for inner-shelf depositional environments: i) thick sandy deposits are found in water shallower than 40 m where the underlying geologic structure is synclinal; ii) deeper water (40-50 m) exhibits muddy layers interbedded with the sands; iii) areas atop anticlinal structures contain basal gravel (>1cm diameter). The first sedimentary style is interpreted to represent the inner-shelf depocenter through which most sediment passes as it moves seaward. Finer particles are easily resuspended and transported seaward, leaving behind coarser-grained sands. The synclinal structure in these areas creates high rates of accumulation, and basal portions of the transgressive sequence cannot be reached through traditional coring methods. The second style is interpreted to record the location of mud deposits created by large flood events, subsequently buried by inner-shelf sands. The presence of inter-bedded sand and mud on the inner shelf suggests that the locations of flood deposits are not only controlled by physical parameters (waves and currents) but also by the magnitude of the flood event. The third style is interpreted to record a compressed transgressive sequence with the basal gravel layers representing a paleo-beach. These cores are positioned near the axis of the Little Salmon Anticline, and their location on top of a structural high causes low accumulation rates that allow vibracore penetration into the basal transgressive stratigraphy. The presence of gravel is somewhat enigmatic, because the Eel River does not supply much gravel to the margin today. The variety of sedimentary styles shows that the inner-shelf environment of the Eel Margin is a dynamic depositional regime controlled by many factors.

### *b) Evaluation of sediment transport seaward from shelf to slope*

Eel River sediment is rapidly (<60 days) deposited at the head of the Eel Canyon during a winter flooding season. $^{7}$Be results show that the head of the canyon is receiving flood-derived sediment all along the rim of the canyon. The thickness of the winter sediment layer seems to be dependent on canyon morphology. Thicker deposits are found in the canyon thalwegs (~18 cm) than in areas between the canyon channels (~6 cm). Physical structures dominate the sediment fabric, especially in the channel thalwegs where little bioturbation is observed. These results imply that sediment is focussed into the channel thalwegs over seasonal time-scales.

The distribution of suspended sediment over the open slope and canyon is spatially and temporally variable. During both summer and winter conditions, suspended-sediment concentrations are greater (~2 times) within the Eel canyon than on the open slope. Temporally, the two regions show some similarities. The highest concentrations (3-10 mg/l) were observed during winter in intermediate nepheloid layers (INLs) at shelf-break depths (~70-150 m). Deeper INLs (>150 m water depth) dominate during the summer, but have lower sediment concentrations (1-2 mg/l) and do not extend very far seaward (<5 km from the upper slope). A relationship between current direction, water-column stratification and seaward extent of the shelf-break INL was observed during the winter months over the open slope. The shelf-break INL extended >20 km seaward in March during a period of persistent seaward currents, moderate vertical sediment fluxes (14 $g/m^2/d$, as observed at the Y450 mooring) and strong density stratification. In contrast, the shelf-break INLs extended <7 km seaward in January, when the currents were onshore, the stratification was weaker and vertical sediment fluxes were low (3 $g/m^2/d$).

Preliminary results from the Eel Canyon sediment traps indicate that vertical sediment fluxes are much higher over the upper canyon than the open slope (during the winter). Average flux to the bottom trap (~15mab) over a six-month period was 721 $g/m^2/d$ in the canyon, compared to the maximum flux recorded on the open slope (over 4 years) of only 40 $g/m^2/d$.

**c) *STRATAFORM coordination***

Program planning was completed at the annual meeting (Monterey, Dec 99) and several conferences and workshops: AGU/ASLO Ocean Sciences symposium (Jan 00), EuroSTRATAFORM workshops (Nov 99, Jun 00), modeling workshop (Jun 00), shelf workshop (Jul 00). The five cruises involved coordination of multiple investigators. The STRATAFORM final volume was planned and chapter content identified. An implementation workshop for EuroSTRATAFORM was prepared for December 2000. A special session was organized for the December 2000 AGU meeting. Plans were finalized for a Chapman Conference in June 2001. The *Thompson* cruise in March, and trips to the Great Salt Lake in August and to IFREMER (Brest, France) in September allowed investigation of PROD, GLAD800, and calypso coring systems.

## IMPACT/APPLICATIONS

For a mountainous collision margin (typical of the Pacific Ocean), this research provides data needed to understand strata formation and allows specifically for better interpretation of long cores recording the environmental history of the Eel margin. Because much of the insight gained about strata formation is generic in nature, this work interfaces with the intermediate and long time scales of the nested spectrum studied by STRATAFORM.

## TRANSITIONS

The research results are being utilized by numerous other STRATAFORM groups; for example: by shelf seabed group, because microfabric and radioisotope profiles are part of the integrated effort to document seabed characteristics; by boundary-layer hydrodynamics group, because observations document the seabed at instrument sites; by plume-dynamics group, because flood deposits demonstrate the fate of plume sediment; by slope sedimentation group, because trap fluxes document sediment deposition rates; by seismic stratigraphers, because core logs provide impedance profiles; by stratigraphic modeling group, because sediment accumulation rates and biological mixing rates are important parameters.

## RELATED PROJECTS

As described above, examples of the related projects are: R. Wheatcroft, shelf seabed; R. Sternberg, boundary-layer hydrodynamics; R. Geyer, plume dynamics; C. Alexander, slope sedimentation; N. Driscoll, seismic stratigraphy; D. Swift, stratigraphic modeling. The entire STRATAFORM program is related to the efforts for program coordination.

## PUBLICATIONS (refereed publications during FY00)


Bentley, S.J. and C.A. Nittrouer, submitted. Emplacement, modification and preservation of event stratigraphy on a flood-dominated continental shelf, Eel shelf, northern California. *Jour. Sed. Res.*

Mullenbach, B.L. and C.A. Nittrouer, 2000. Rapid deposition of fluvial sediment in the Eel Canyon, northern California. *Cont. Shelf Res.,* 20.

Sommerfield, C.K., R.C. Aller and C.A. Nittrouer, in press. Sedimentary C-S-Fe relationships in modern and ancient diagenetic environments of the Eel River Basin (USA). *Jour. Sed. Res.*

Sommerfield, C.K., C.A. Nittrouer and C.R. Alexander, 1999. $^{7}$Be as a tracer of flood sedimentation on the northern California continental margin. *Cont. Shelf Res.*, 19, 335-361.